A WATER TABLE - WATER QUALITY MANAGEMENT RESEARCH FACILITY FOR THE SOUTHEASTERN COASTAL PLAIN: PROGRESS REPORT

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ABSTRACT

A research facility to investigate automation of controlled drainage/subirrigation (CDSI) systems for soils in the southeastern Coastal Plain has been constructed at the Coastal Plains Soil and Water Conservation Research Center, Florence, SC. This facility contains four separate systems, each consisting of three drain lines connected to individual control tanks. Water is added to or removed from the control tanks to regulate field water table depths. Each system is managed by a datalogger/controller that activates relays and solenoids to adjust the control tank water elevation to the position required to maintain target water table depths in the field. Surface runoff volume will also be measured. Water samples collected from control tanks, drain discharge lines, wells, and surface runoff will be analyzed to determine chemical concentrations. Future work will include the development of more sophisticated automatic control, management of the water table to reduce off-site water quality degradation, and modelling of water and chemical movement through the soil profile.

Keywords. Water table, Controlled drainage, Subirrigation, and Water quality.

INTRODUCTION

Systems that reduce and/or control wet soil conditions, store excess water, and supply water for crop requirements during drought periods would conserve water and increase crop productivity in many areas of the southeastern Coastal Plain. Large areas of the region have water tables within 1.5 meters of the soil surface during a significant part of the year. The development of DRAINMOD, a model that allows the evaluation of the drainage-water table control systems for a range of soil and climatic conditions during both drainage and subirrigation, significantly aided the design and evaluation of these systems for a wide range of soils and climates (Skaggs 1978, 1981). However, design and management criteria for water table management (WTM) or controlled drainage/subirrigation (CDSI) systems on these soils have not been fully developed (Shirmohammadi et al., 1992). These criteria must include techniques for reducing contaminants in surface and ground waters (Thomas et al., 1992).

Although investigators have shown that CDSI provides most of the water needed for crop production (Doty and Parsons, 1979), implementation of current and improved management criteria is often limited by lack of automated and/or remotely-operated control structures.

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Manual adjustment of control structures for controlled-drainage and CDSI systems is difficult and is often not accomplished because of conflicts in the work schedule. Recent developments have resulted in prototypes of systems to automate this process and to link it to weather forecasts and computer data bases (Fouss, 1985 and Fouss and Cooper, 1988).

The impact of WTM or CDSI on water quality has been studied on a limited basis. Fields with conventional subsurface drains lose more nitrogen than fields with improved subsurface drainage (Jacobs and Gilliam, 1985). In another study, about 10 times more nitrate was lost from fields with good subsurface drainage than from fields with primarily surface drainage (Gilliam and Skaggs, 1986). However, reductions of about 50 percent in nitrate movement into drainage outlets from controlled drainage systems were reported by Gilliam et al. (1979). Evans et al. (1989) reported that average nitrate-nitrogen concentrations for controlled-drainage systems remained below 10 mg/L in 11 of 13 studies in the southeastern Coastal Plain. Thomas et al. (1992) reported limited data regarding phosphorus and pesticide losses from conventional subsurface drainage systems and no pesticide-transport data from controlled drainage and CDSI systems. They concluded that additional research is needed, particularly with respect to pesticide losses through these systems.

There is less annual drainage discharge with controlled drainage or CDSI than with conventional subsurface drainage (Evans et al. 1989). Consequently, more water is available for evapotranspiration and vertical seepage. Additionally, the higher water table increases the system sensitivity to events such as rainfall and chemical applications. The objectives of this paper are to describe a research project and facility that is directed toward development of an automated management system for CDSI and to report initial progress. This facility will also be used to investigate the movement of agricultural chemicals in water table systems and to develop management criteria that will minimize movement of agricultural chemicals out of the field, into either surface outlets or the ground water.

SYSTEM DESCRIPTION

A water table management research facility has been installed in a 1-ha Carolina Bay at the Coastal Plains Soil and Water Conservation Research Center, USDA-ARS, Florence, SC. The soils in the area are Coxville loam (*Clayey, kaolinitic, thermic Typic Paleaquults*) and Dunbar loamy fine sand (*Clayey, kaolinitic, thermic Aeric Paleaquults).* The facility consists of four separate systems, each with a sump outlet. Within each system, three subsurface drain lines, which enter the sump separately, are spaced 15 meters apart. Each drain line is connected to a separate control tank so that each drain line can be controlled independently. The systems are positioned in pairs, such that two are located immediately adjacent to each other with respective exterior drain lines spaced 15 meters apart; thus, each pair can also be operated as a combined system consisting of six drain lines with each drain line controlled by a separate tank. Schematic diagrams showing the soil boundaries, system locations, and water table control system are included as Figs. 1 and 2.

The water table elevation in the soil adjacent to the drain line can be adjusted by changing the water elevation in the control tanks, either by energizing a pump to remove excess water or by opening a solenoid valve to add water from a pressurized water supply. The system was initially managed using float controls in the early stages of development, but the first phase of an automatic control system is now operational. This control system consists of a central

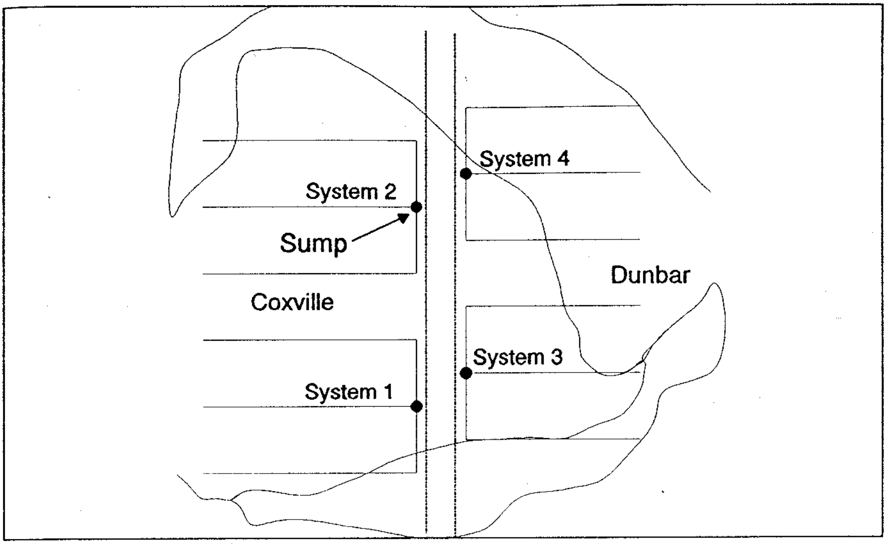


Figure 1. Schematic diagram of four water table management systems on two southeastern Coastal Plains soils, Coxville loam, and Dunbar loamy fine sand.

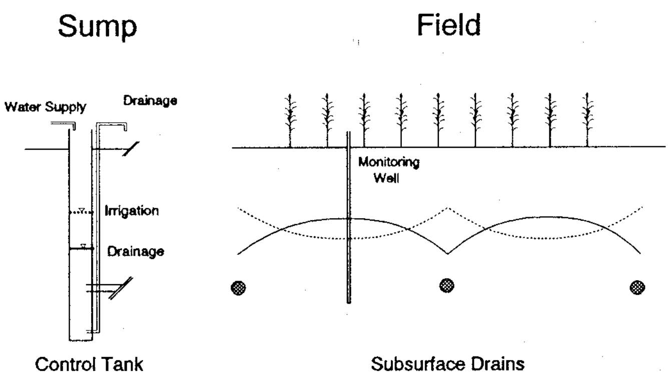


Figure 2. Schematic diagram of water table management system including drain lines, control tank, and monitoring wells. Each sump contains three control tanks, one for each drain line.

datalogger/controller (Campbell Scientific Inc. CR-7X[**]) to measure and record sensor values

[**]Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the U. S. Dept. of Agr. and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

and to energize switches (relays, solenoids, etc.) as directed by a control algorithm stored in the datalogger/controller. Water level sensors presently include pressure transducers (Druck model PDCR 950, 2.5 psig) and linear resistors (Metritape Aquatape type AGS). Water level sensors are located in each control tank and in wells. The wells are located in each plot at selected distances from the drain lines (drain line, quarter-spacing, and half-spacing). Currently, water flow into and out of the control tanks is measured with positive displacement flow meters with manual readout, but pulse-output flow meters will be installed on both the supply and discharge lines for each control tank in the near future.

Communication between the field datalogger/controller and a personal computer in the laboratory is accomplished using a radio-frequency (RF) telemetry system manufactured by Campbell Scientific, Inc. The telemetry system consists of a base station connected to the computer, communication software, UHF portable transmit/receive radios at both the base station and the field station, antennae, and modems. Memory in the datalogger/controller is adequate to store the program and data for several days and will be interrogated each day when fully implemented. The system status or value of any control point or sensor can be determined at any time. Also, the datalogger/control algorithm can be edited and the values of all parameters can be adjusted remotely.

The current automatic control algorithm includes a single set of control parameters, one for the irrigation cycle and one for the drainage cycle, for each control tank. These parameter values can be altered via the remote computer or on site via keyboard entry. When fully implemented, the automatic control program will operate with feedback from water table measurements in each of the field plots. As more is learned about the system, soils, and control dynamics, it may be possible to simplify the system by eliminating the feedback portion of the control program and relying predominantly on long-term weather records or soil properties and weather forecasts.

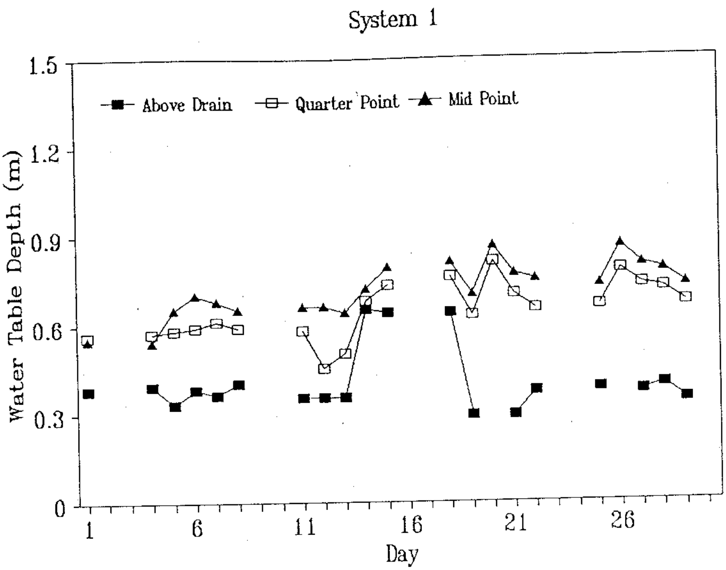
Refrigerated pump samplers (Isco model 3700) will be installed adjacent to the control tanks in each system to collect water samples for quality analysis. Plans are now being completed for the fabrication and installation of surface runoff collection and measurement equipment for each system.

OPERATIONS

Because of the delay in installation of the water supply and an early season drought, it was impossible to achieve adequate water table control in any system in 1991, especially in Systems 3 and 4, where a higher fraction of the coarse-textured soil is located. In fact, corn suffered from drought stress at the mid-point between drains even on the fine-textured soil. The primary reason for this, especially on the Coxville loam, is that much of the water in the root zone was extracted by the crop before water and controls were available for subirrigation. By the time that water was available, the hydraulic conductivity of the soil was so low (because much of the soil profile was not saturated) that it was not possible to raise the water table.

In 1992, water table control was intermittent during the late winter and early spring months because of conversion from an unreliable, temporary water supply to a permanent one and because the control system was being converted from float control to automatic control using the datalogger/controller and sensors. Water table depths at three locations relative to the drain lines for Systems 1 and 2 during a 4-week period during summer are shown in Fig. 3. The water table elevations at the above-drain location are very similar to the water elevations in the control tank. In these two systems, the water table at the mid-point between drain lines was generally responsive to the control tank water elevation. This was not true in the other two systems.

Although 2-3 times more water was pumped into System 4 as into Systems 1 or 2, a water table



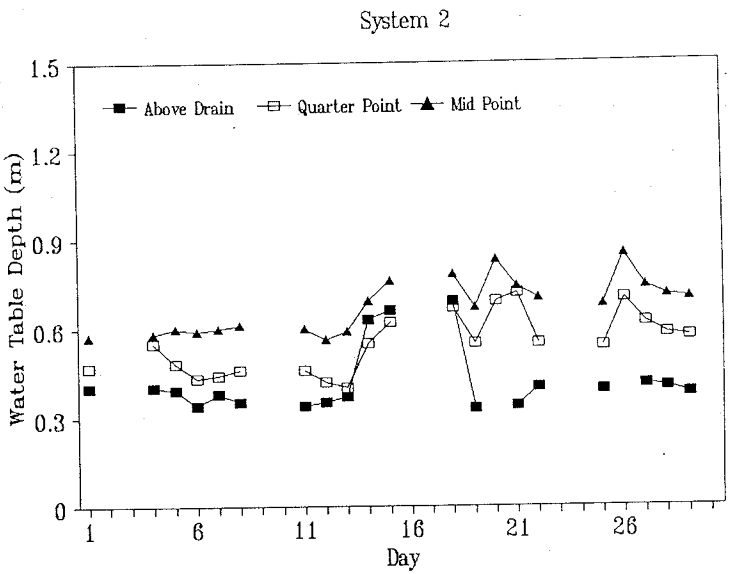


Figure 3. Water table depths during a 4-week period in 1992 at three locations relative to subsurface drains for two water table management systems on a Coxville loam soil in the southeastern Coastal Plain.

did not exist at the drain-line depth in System 4. A water table was measured at the quarter-point and occasionally at the mid-point between drains in System 3. Based on these preliminary data it may not be possible to successfully maintain water tables in the Dunbar portion of these two systems.

Although the system was not fully operational and the water supply was not installed until mid-season, a corn crop (*Zea mays* c.v. Hybrid Pioneer 3165) was planted in 1991 to evaluate soil variation. It was suspected that there would be considerable variation in soil pH and nutrient level (confirmed by measurement) and other chemical properties. Lime was applied based on pH measurements and soil type. However, soon after corn emergence, it became evident that there were significant corn growth differences. After further sampling, it was determined that there was significant variation in soil pH in this area. Addition of more lime in both fall 1991 and spring 1992 was required to significantly alter soil pH. Barley was grown during the winter of 1991-1992 to help diagnose problem areas using crop growth differences caused by soil pH variation. Sorghum was planted in 1992, to evaluate both soil variation and water table management system performance. The later planting date for sorghum allowed necessary construction in the immediate area to continue, accommodated delays caused by rainfall during the late winter and early spring, and allowed the completion of soil surface smoothing in the experimental area. A final adjustment in soil pH will probably be needed in fall 1992, following harvest of the sorghum crop.

FUTURE PLANS

Simulations of water table elevations, chemical concentrations, and movement of agricultural chemicals through the soil profile will be accomplished using DRAINMOD, CREAMS, a linked version of DRAINMOD and CREAMS, and other appropriate models. Models or their components will be evaluated, modified, and/or developed as necessary to describe these processes in Coastal Plain soils. Initial studies will include determination of nitrogen and phosphorus losses from the system, but later studies will include selected pesticides. Samples collected from the control tanks, surface runoff, and wells will be analyzed to determine concentrations of nutrients and pesticides for establishing baseline levels for selected chemicals and to evaluate water and/or soil management practices studied in the future.

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